TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 130

MODEL SUPPORTS AND THEIR EFFECT ON THE RESULTS OF WIND TUNNEL TESTS.

By David L. Bacon,
Langley Memorial Aeronautical Laboratory.

February, 1923.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 130.

MODEL SUPPORTS AND THEIR EFFECT ON THE RESULTS OF WIND TUNNEL TESTS.

By David L. Bacon.

Summary.

The airflow about a model while being tested is often sufficiently affected by the model support to lead to erroneous conclusions unless appropriate corrections are used. In this paper some new material on the subject is presented, together with a review of the airfoil support corrections used in several other laboratories.

The part of a balance supporting a model in the air stream of a wind tunnel experiences a force which must be deducted from the total force measurement in order to find the force on the model alone. This correction is known as "spindle drag" or "wire drag" and its exact value can easily be measured on the balance if the model is disconnected from the spindle and supported in close proximity thereto by some auxiliary means.

More important than the actual drag of the spindle itself, is the disturbing effect which the presence of the support exerts on the airflow about the model. This is termed "spindle interference" or "wire interference." Spindle interference depends primarily on the position of the spindle with respect to the model. As an extreme example of interference we may take the case illustrated in Figures 1 and 2, of a sphere supported in a wind tunnel by a bent spindle "A" and by a fine wire "B". The measured drag of the sphere, spindle, and wire is .372 kg, and that of the wire alone .014 kg, but if we remove the wire and repeat the measurement on sphere and spindle we find the drag to be not .358 kg, but .169 kg. Thus we see that while the wire drag amounted to only 4 per cent, its interference is of the order of 50 per cent of the gross measurement.

Similarly we could retain the wire and, by removing the spindle, get values for spindle drag and spindle interference. Unfortunately the sum of the spindle and wire interferences thus measured, one at a time, is not rigorously equal to the combined interference of the spindle and of the wire acting simultaneously. Thus it is impractical to eliminate entirely the support interference in wind tunnel research, because the interferences of two supports on the same model may be mutually interdependent. In the testing of airfoils and of model airplanes, the elongated shape of the model permits such separation of the main and auxiliary supports that the secondary interferences of the supports may probably be made negligibly small.

Limiting ourselves to a discussion of airfoil testing, we find that there are now in use in this country four different types of airfoil supports and fully as many more abroad (See Figure 3). We also note that some laboratories correct their tests for support interference, while others neglect it entirely. Even among those who introduce interference corrections, there is no uniformity of practice as to the method of obtaining the correction.

In the following tests a 4" x 24" U.S.A.16 airfoil was supported on the skids of the N.A.C.A. wire balance, and the tunnel operated at a speed of 20 meters per second (65.6 ft. per sec); then, with all other conditions remaining strictly constant, a dummy spindle 9.5 mm (3/8") in diameter was brought into close proximity to the model, first at a wing tip and then successively to the upper and lower surfaces at the mid points of the span, shown in Figure 4 as positions A, B, and C respectively. The lift and drag coefficients computed from these tests are given in Table 1 and are plotted as polar curves in Figure 5.

If we neglect the disturbing effect of the spindle on the wires, and of the wires on the spindle interference we may plot curves of drag interference for the three spindle locations, as shown in Figure 6.

The end spindle has little effect at low lift coefficients, but by reducing the maximum lift, it introduces an appreciable correction when the angle of attack is increased. At lift coefficients less than .3 the two center spindles have opposite, and nearly equal effects, the one on the lower surface decreasing the drag, and that on the upper surface increasing it. At higher lift coefficients the interference of spindle B, on the upper surface increases uniformly until it adds 40% to the drag of the airfoil. The interference of spindle C, on the lower surface, reaches a maximum negative value of 13% at a lift coefficient of .5 and then decreases to zero, becoming positive for lift coefficients above .85.

An attempt was made to get some information on the interference of the skids used with the wire balance. This was done in the following manner: Using an N.P.L. type of balance and a wing tip spindle, three drag measurements were made: (a) of a wing alone, (b) of a wing with two skids attached to the lower surface, and (c) of a single skid fastened directly to the balance spindle. The drag of (a) was found equal to that of (b) - 2 (c) within the error of measurement of the balance.

Although other investigators have called attention to the existence of support corrections, the large error which may be caused by neglecting them is not generally appreciated in engineering circles. It is therefore to be hoped that the above tests, together with those quoted in the Appendix, will serve to show the danger of attempting to compare or apply airfoil coefficients, regardless of origin, unless adequate interference corrections are known to have been applied.

Appendix.

A communication from the Eiffel Laboratory calls attention to the interference caused by the supports until recently used in that wind tunnel. The report states that the drag coefficients previously issued from that laboratory were uniformly high because of the airfoils having been supported on brackets attached to the upper surface, and that by supporting the airfoil from the lower surface, spindle interference can be avoided. Eiffel then explians that the interference affects only the induced drag and not the profile drag, hence its effect can be treated in a manner similar to that used for aspect ratio, and an example is given to demonstrate that, within certain limiting values of λ, the drag of a wing of aspect ratio λ held by a certain fixture screwed to the upper surface is equal to that of one of the same area and profile having an aspect ratio $\lambda - 2$ held by that bracket on the lower surface. The magnitude of this correction is shown in Figure 7.

No proof is offered to show that the support on the lower surface does not cause interference, and it seems doubtful that this should actually be the case. In fact it is probable that at low angles of attack the true drag lies intermediate between these two conditions and that a more accurate drag coefficient would be obtained by correcting to an effective aspect ratio of $\lambda - 1$ the Eiffel tests of airfoils held from the upper surface, and to $\lambda + 1$ those in which the airfoils were held from the lower surface.

There are also available data from Amsterdam giving the drag of an airfoil when held by two types of center support. For the sake of comparison we have plotted in Figure 7 the drag when held by spindles on the upper surface in per cent of that when held from the lower surface. These R.S.L. curves show a decided interference effect on the profile drag at low lift coefficients, due probably to the thickness of the airfoils used for the test.

The University of Toronto has made an investigation of the interferences of end and crank spindles from which we have derived the curves of Figure 8. The end spindle interference is so low as to be almost negligible, the values being approximately one-quarter of those obtained in the N.A.C.A. test. This may be partially explained by the ratio of spindle diameter to airfoil chord, .0936 for our tests and .0635 for University of Toronto, though this 50% increase in relative diameter is probably not the sole cause for disagreement. The curve for the crank spindle bears a strong resemblance to our curve for a support at the center of the lower surface. In this connection it should be noted that while most of the crank spindle is of circular section it is possible to make that portion which is perpendicular to the span of the model, of streamline section.

The support used in the 8-foot tunnel at the Washington Navy Yard is so carefully streamlined that, although it is attached to the upper side of the wing, its interference has been found to be so small that it may be neglected.

At the Göttingen Laboratory no corrections for wire interference were being applied in 1921, though a special research to determine this correction was then under consideration.

Bibliography.

R. & M. No. 148, Bairstow, Pannell, Lavender, Fage and Cowley.

No. 198, Relf, Bryant, Irving, Pannel and Campbell.

No. 244, Pannell and Campbell.

N.A.C.A. Technical Note No. 37, Davidson and Bacon.

N.A.C.A. Technical Report No. 146, Zahm.

U. S. A. Technical Orders No. 12.

University of Toronto Bulletin No. 2, Paper No. 1, Parkin.

Report of the First International Congress of Aerial Navigation, Robert.

G. Eiffel, L'Aerophile, 1-15 August, 1922.

Verslagen En Verhandelingen Von Den Rijks-Studiedienst Voor De Luchtvaart - Amsterdam Deel 1, 1921, Wolff.

Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen 1921, Prandtl.

Langley Field, Va.

February 10, 1923.

Table 1.

INTERFERENCE ON U.S.A. 16

	NONE			END SPINDLE			SPINDLE ABOVE			SPINDLE BELOW			WIRE SCREEN		
α	C_L	C_D	L/D	C_L	C_D	L/D	C_L	C_D	L/D	C_L	C_D	L/D	C_L	C_D	L/D
-2°	-.058	.0159	-3.7										.032	.0164	1.9
0°	.117	.0141	8.2	.149	.0137	10.9	.130	.0151	8.6	.130	.0132	9.8	.185	.0164	11.1
2°	.324	.0166	19.5	.344	.0168	20.5	.330	.0197	17.0	.344	.0146	23.5	.324	.0206	15.8
4°	.474	.0240	19.7	.480	.0243	19.8	.480	.0301	15.9	.486	.0213	22.9	.454	.0284	16.0
6°	.610	.0342	17.8	.615	.0364	16.7	.603	.0430	13.9	.635	.0304	21.0	.590	.0394	15.0
8°	.745	.0458	16.2	.778	.0540	14.4	.740	.0610	12.1	.745	.0433	17.3	.726	.0550	13.2
10°	.860	.0615	14.1	.895	.0680	13.2	.850	.0810	10.6	.870	.0635	13.7	.843	.0720	11.7
12°	.960	.0810	12.0	.920	.109	8.5	.960	.103	9.4	.910	.110	8.3	.955	.0915	10.4
14°	.950	.145	6.6	.910	.192	4.8	.920	.193	4.8	.910	.139	6.5	1.04	.121	8.6
16°	.890	.233	3.8	.870	.247	3.5	.895	.243	3.7	.890	.228	3.9	1.06	.167	6.3
18°	.870	.264	3.3	.843	.280	3.0	.875	.266	3.2	.840	.260	3.2	1.07	.226	4.7
20°	.800	.286	2.8										1.00	.286	3.5

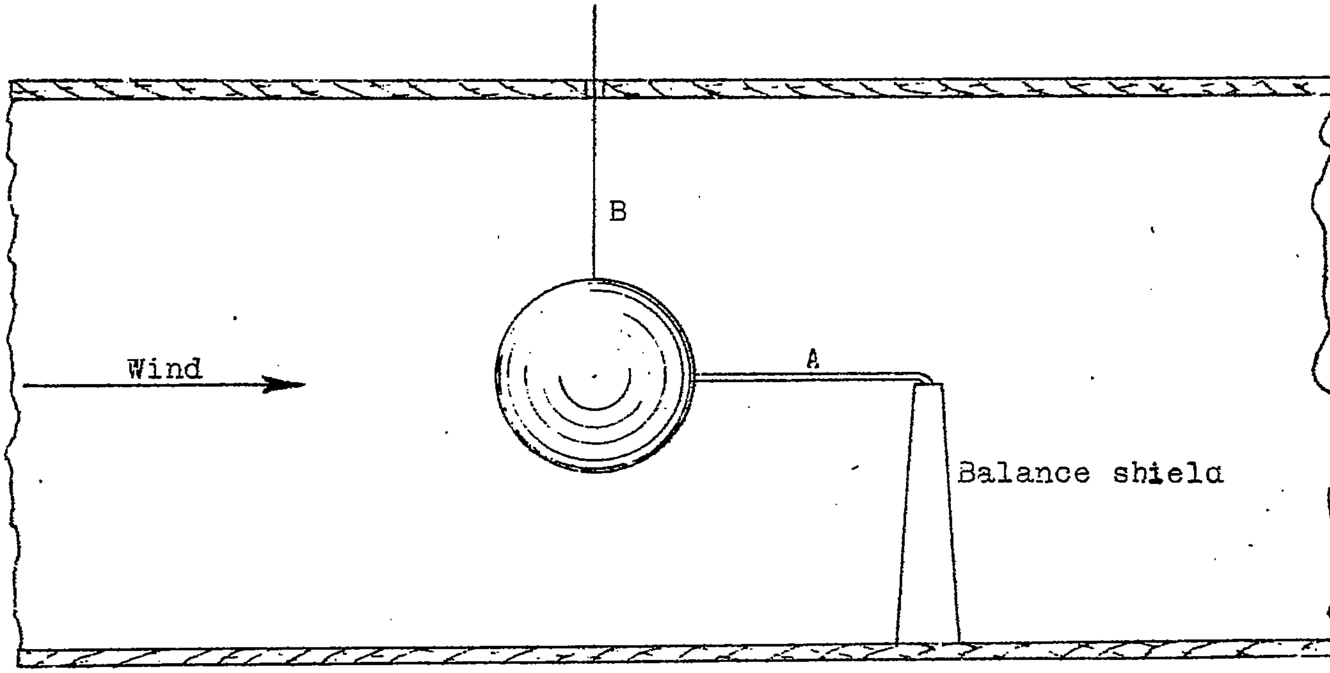

Fig.1 Sphere with spindle and wire supports

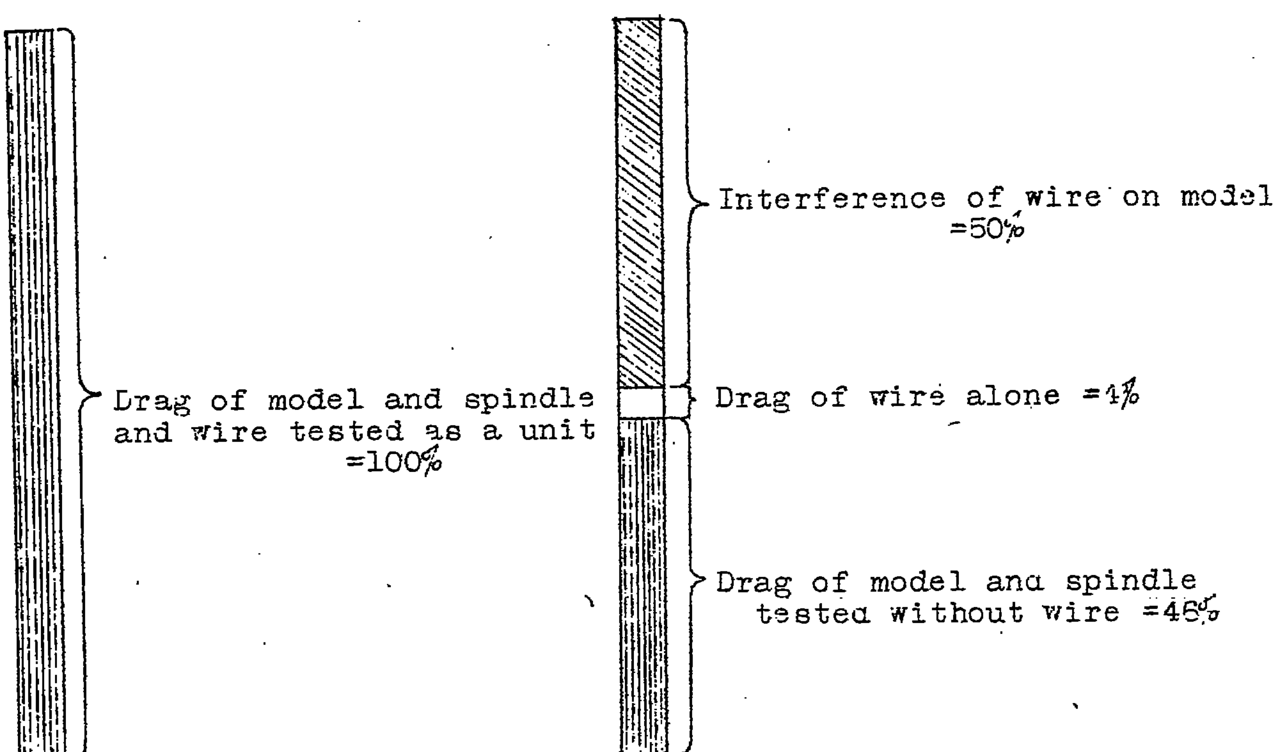

Fig.2 Resistance measurements on a sphere mounted as in fig.1

Figs.1 and 2

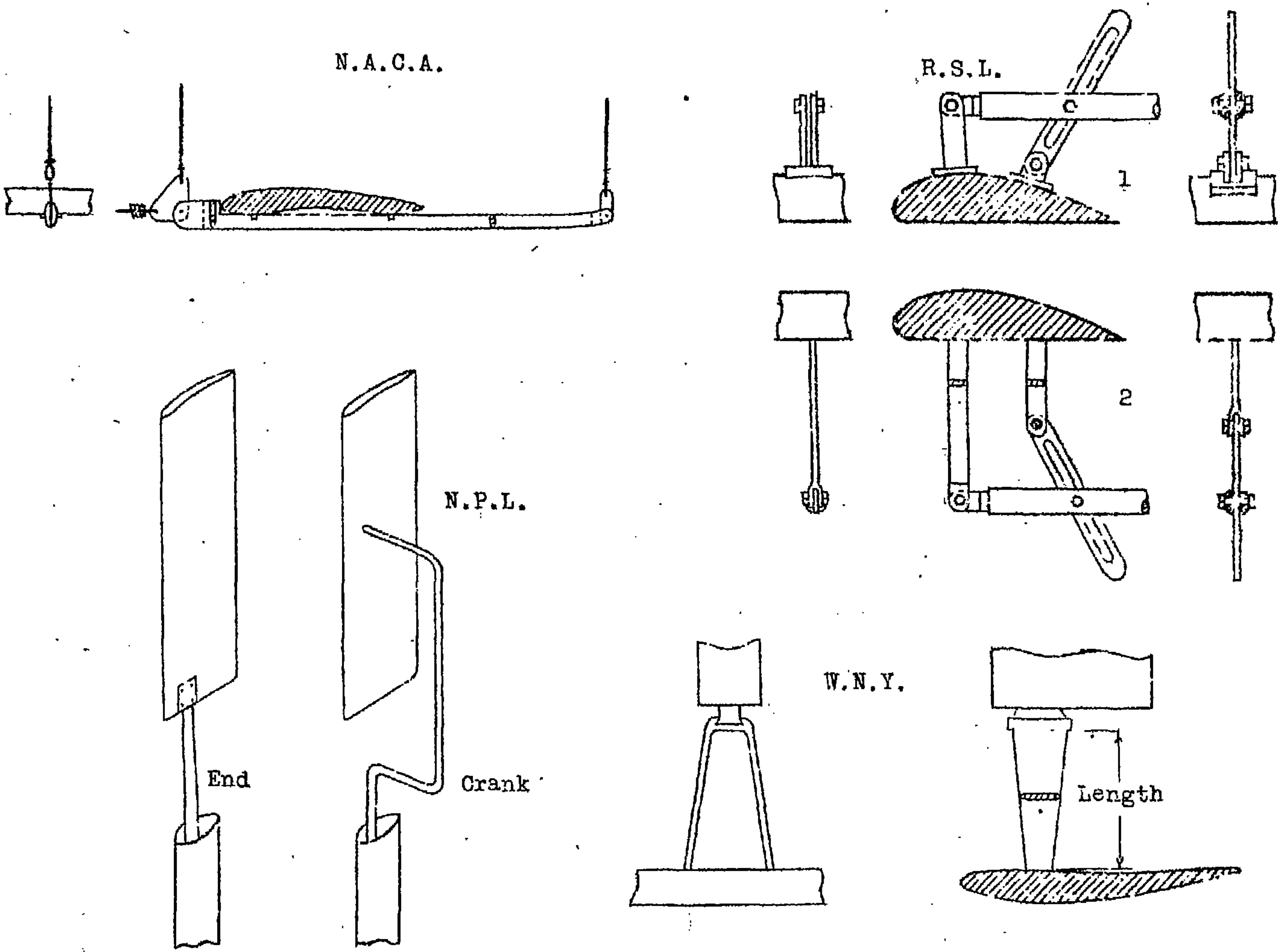

Fig. 3 Types of airfoil supports

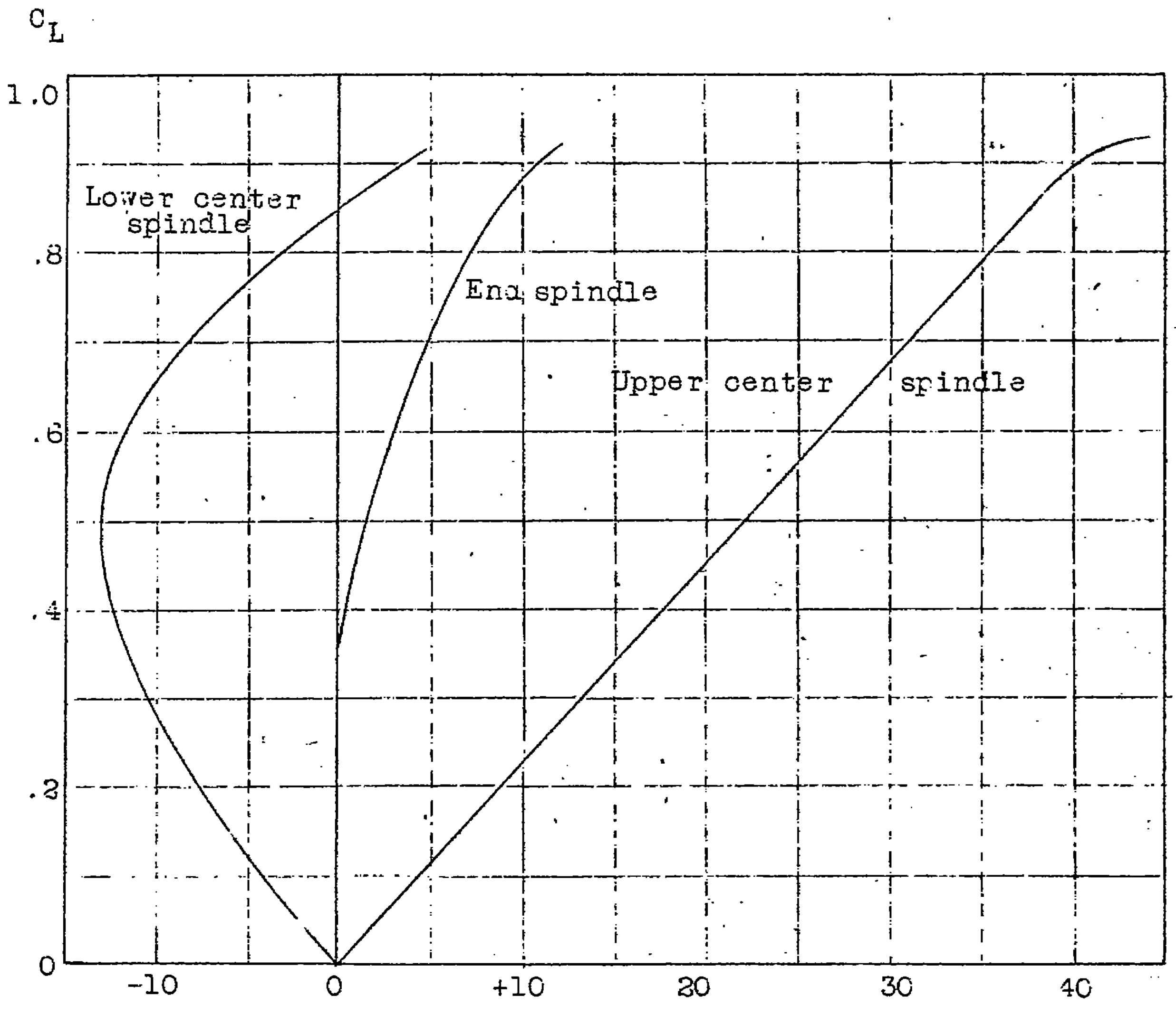

Fig.6 Interference of dummy spindles on U.S.A.16

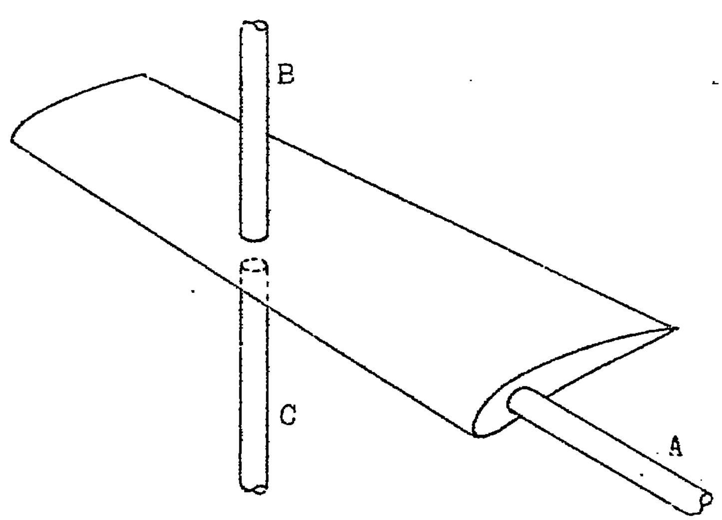

Fig.4 Positions of dummy spindles

Figs.4 and 6

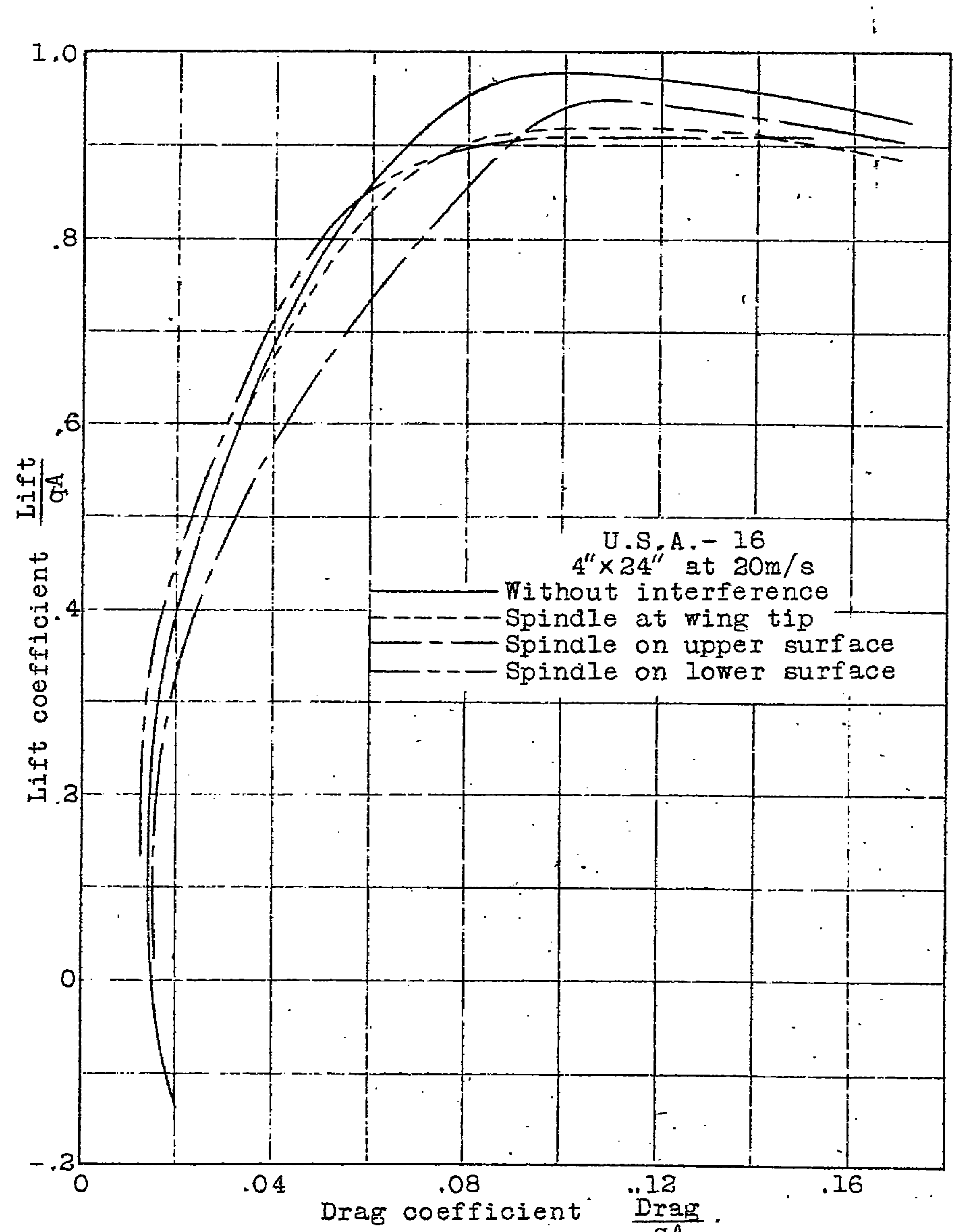

Fig.5 Lift and drag coefficients with interferences.

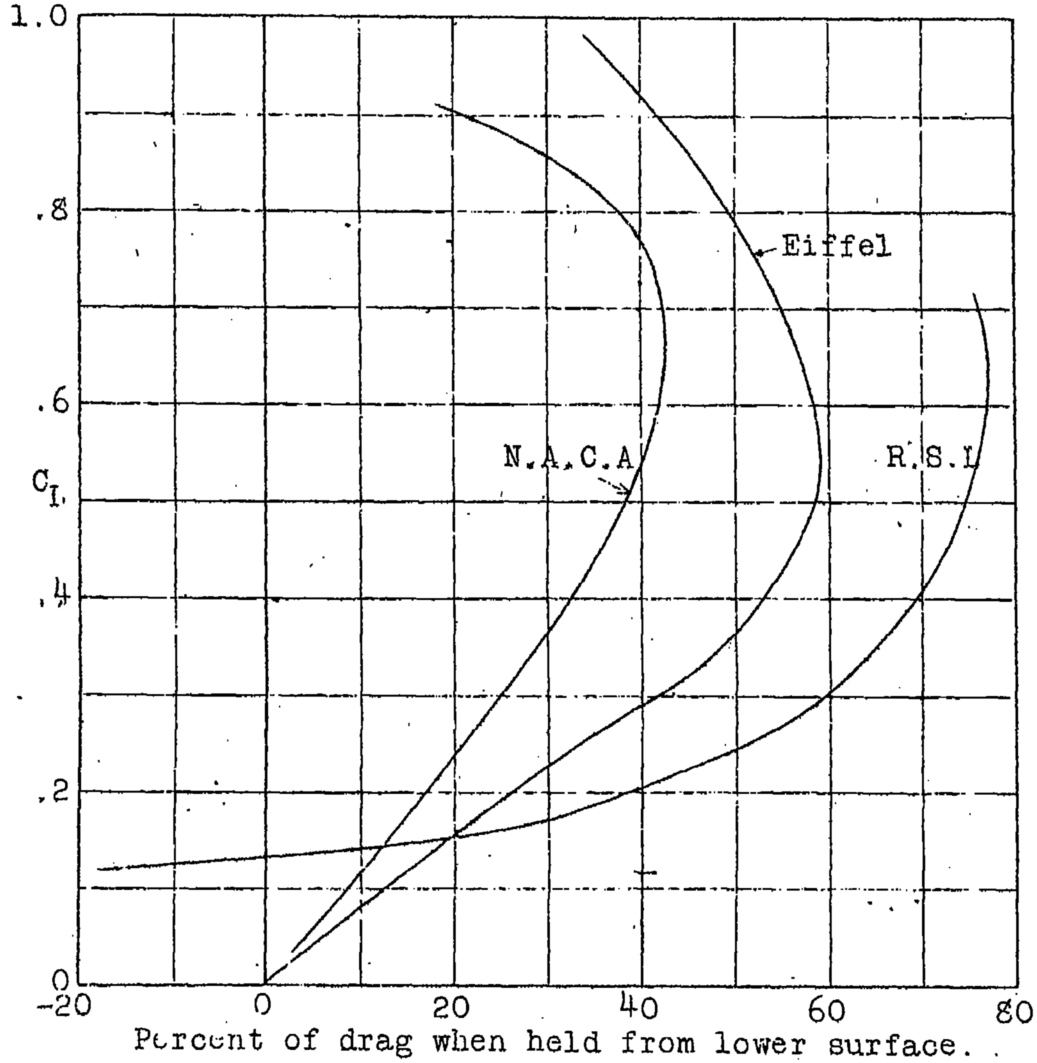

Fig.7 Interference of spindle on upper surface if spindle on lower surface gives true drag.

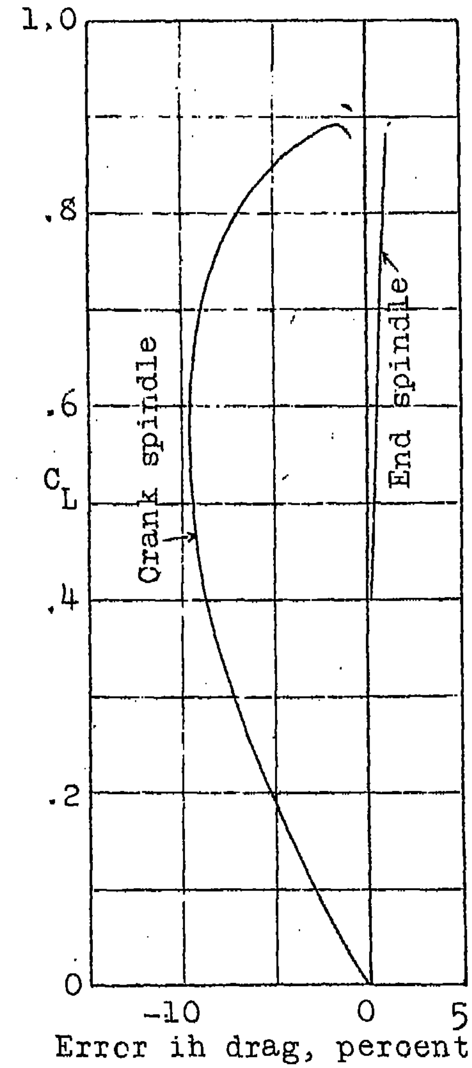

Fig.8 Spindle tests from University of Toronto.